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Attorney Docket No.	UF-243X
First Inventor or Application Identifier	Howard M. Johnson
Title	Materials and Methods for Inhibition of IgE Production
Express Mail Label No.	EK318904486US

JC862 U.S. PTO 09/648864 08/25/00

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

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   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
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8. [ ] 37 C.F.R.§3.73(b) Statement *(when there is an assignee)* [ ] Power of Attorney
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15. [X] Other: Claims priority to USSN 60/151,026, filed August 27, 1999

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Inventor(s): Howard M. Johnson, Mustafa G. Mujtaba

Entitled: Materials and Methods for Inhibition of IgE Production

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Applicant or Patentee: Howard M. Johnson, Mustafa G. Mujtaba
Serial or Patent No.:
Filed or Issued: August 25, 2000
For: Materials and Methods for Inhibition of IgE Production

Attorney's Docket No. UF-243X

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9 (f) and 1.27 (c)) – NONPROFIT ORGANIZATION

I hereby declare that I am an official empowered to act on behalf of the nonprofit organization identified below:

NAME OF ORGANIZATION University of Florida
ADDRESS OF ORGANIZATION 223 Grinter Hall
Gainesville, FL 32611

TYPE OF ORGANIZATION

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I hereby declare that the above identified nonprofit organization qualifies as a nonprofit organization as defined in 37 CFR 1.9 (d), for purposes of paying reduced fees under section 41(a) and (b) of Title 35, United States Code, with regard to the invention described in the above-identified:

[ ] PATENT [X] APPLICATION

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*NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring their status as small entities. (37 CFR 1.27)

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NAME OF PERSON SIGNING Thomas E. Walsh, Ph.D.
TITLE IN ORGANIZATION Director of Sponsored Research
ADDRESS OF PERSON SIGNING 223 Grinter Hall
Gainesville, FL 32611

SIGNATURE T Walsh DATE August 25, 2000

DESCRIPTION

MATERIALS AND METHODS FOR INHIBITION OF IgE PRODUCTION

The subject invention was made with government support under a research project supported by National Institute of Health Grant No. CA69959 and R37AI25904. The government has certain rights in this invention.

Cross-Reference to a Related Application

This application claims the benefit of U.S. Provisional Application No. 60/151,026, filed August 27, 1999.

Background of the Invention

The interferons have been classified into two distinct groups: type I interferons, including IFNα, IFNβ, and IFNω (also known as IFNαII); and type II interferons, represented by IFNγ (reviewed by DeMaeyer *et al.*, 1998). In humans, it is estimated that there are at least 17 IFNα non-allelic genes, at least about 2 or 3 IFNβ non-allelic genes, and a single IFNγ gene.

IFNα's have been shown to inhibit various types of cellular proliferation. IFNα's are especially useful against hematologic malignancies such as hairy-cell leukemia (Quesada *et al.*, 1984). Further, these proteins have also shown activity against multiple myeloma, chronic lymphocytic leukemia, low-grade lymphoma, Kaposi's sarcoma, chronic myelogenous leukemia, renal-cell carcinoma, urinary bladder tumors and ovarian cancers (Bonnem *et al.*, 1984; Oldham, 1985). The role of interferons and interferon receptors in the pathogenesis of certain autoimmune and inflammatory diseases has also investigated (Benoit *et al.*, 1993).

IFNα's are also useful against various types of viral infections (Finter *et al.*, 1991). Alpha interferons have shown activity against human papillomavirus infection, Hepatitis B,

and Hepatitis C infections (Finter *et al.*, 1991; Kashima *et al.*, 1988; Dusheiko *et al.*, 1986; Davis *et al.*, 1989). In addition, studies with IFNα and IFNγ have shown suppression of IgE production in allergic diseases (Noh *et al.*, 1998; Hofstra *et al.*, 1998; Lack *et al.*, 1996; Dolen *et al.*, 1995; Kimata *et al.*, 1995; Gruschwitz *et al.*, 1993).

Significantly, however, the usefulness of IFNα's has been limited by their toxicity: use of interferons in the treatment of cancer and viral disease has resulted in serious side effects, such as fever, chills, anorexia, weight loss, and fatigue (Pontzer *et al.*, 1991; Oldham, 1985). These side effects often require (i) the interferon dosage to be reduced to levels that limit the effectiveness of treatment, or (ii) the removal of the patient from treatment. Such toxicity has reduced the usefulness of these potent antiviral and antiproliferative proteins in the treatment of debilitating human and animal diseases.

Interferon-tau (IFNτ) is a member of the type I IFN family but, unlike IFNα and IFNβ, IFNτ lacks toxicity at high concentrations *in vitro* and when used *in vivo* in animal studies (Bazer *et al.*, 1989; Pontzer *et al.*, 1991; Soos, Johnson, 1995; Soos, *et al.*, 1995; Soos *et al.*, 1997; Khan *et al.*, 1998). IFNτ was originally identified as a pregnancy recognition hormone produced by trophoblasts cells of the placenta of ruminants such as sheep and cows (Bazer *et al.*, 1991; Godkin *et al.*, 1982; Imakawa *et al.*, 1987; Johnson *et al.*, 1994). It has been reported that a human IFNτ exists (Whaley *et al.*, 1994) but this observation has not been confirmed. Thus, it is currently unknown as to whether there is a human IFNτ. IFNτ exhibits antiviral and cell inhibitory properties are very similar to that of IFNα and IFNβ (Bazer *et al.*, 1989; Pontzer *et al.*, 1991; Soos, Johnson, 1995). However, IFNτ lacks the cellular toxicity associated with high concentrations of IFNα and IFNβ (Bazer *et al.*, 1989; Pontzer *et al.*, 1991). Further, the weight loss and bone marrow suppression that is associated with administering high doses of IFNα and IFNβ to individuals is absent with IFNτ in animal systems (Soos, Johnson, 1995; Soos *et al.*, 1995; Soos *et al.*, 1997). Studies have shown that the N-terminus of type I IFNs play a role in the toxicity or lack thereof for an IFN (Pontzer *et al.*, 1994; Subramaniam *et al.*, 1995).

It has been reported that IFNτ suppresses the humoral and cellular responses in experimental allergic encephalomyelitis (EAE), an animal model for the autoimmune disease, multiple sclerosis (Mujtaba *et al.*, 1998). It has been shown that IFNτ suppresses the responses of lymphocytes to mitogens such as Con A and superantigens such as SEA and SEB (Soos, Johnson, 1995; Soos *et al.*, 1995; Khan *et al.*, 1998). There are also reports, again in the EAE model, that IFNτ and other type I IFNs can induce IL-10 and TGFβ, but not IL-4, production by cells that have already been activated by antigen presenting cells (Soos, Subramaniam *et al.*, 1995; Mujtaba *et al.*, 1998; Mujtaba *et al.*, 1997). IFNτ has also been suggested for use in the treatment of Multiple Sclerosis in humans.

Production of IgE immunoglobulin is important in mediating allergic diseases such as allergic rhinitis, atopic dermatitis, bronchial asthma, and food allergy. Allergic sensitization of mice by intraperitoneal (ip) injection with ovalbumin (OVA) as an allergen and aluminum hydroxide as an adjuvant is a well characterized method of stimulating IgE production *in vivo* (Mancino *et al.*, 1980; Miguel *et al.*, 1977; Beck *et al.*, 1989). When OVA-immunized mice are challenged with aerosolized OVA, they show inflammatory cell infiltration in the submucosal layer of the lungs (Kay *et al.*, 1992; Hamelmann *et al.*, 1996; Hamelmann *et al.*, 1997). IgE can stimulate the release of certain chemotactic mediators from mast cells that can lead to active accumulation of macrophages and granulocytes at the site. Also, production of a further set of inflammatory molecules by these cells can lead to allergic asthma. Thus, allergen specific IgE production by B cells is important in the pathogenesis of allergic diseases.

Conventional therapy for allergic disease consists of decongestants and anti-histamines, which function to reduce symptoms after allergic responses occur. Thus, there remains a need in the art for a treatment of allergic diseases which lacks toxic side effects and functions to block allergic response, thus acting prior to symptomology.

Brief Summary of the Invention

The subject invention concerns novel methods and materials for treating patients afflicted with allergic conditions, such as allergic rhinitis, atopic dermatitis, bronchial asthma and food allergy. The method of the subject invention comprises administering a type I interferon, such as interferon tau (IFNτ), or a chimeric IFN (for example, ovine IFNτ (1-27)/ human IFNαD (28-166)) to a person afflicted with an allergic condition. When administered, the interferon suppresses the production of allergen-specific IgE antibodies without toxic side effects. The subject invention also concerns chimeric ovine/human IFNs which can be used in the methods of the invention.

Brief Description of the Drawings

Figures 1A and 1B show the inhibition of OVA-specific IgE antibody production in OVA-sensitized mice by IFNτ treatment. BALB/C mice were immunized by ip injection with ovalbumin (OVA) mixed with aluminum hydroxide and boosted seven days later. The mice were exposed to aerosolized OVA (1% w/v) on days 19 and 20 after immunization for 20 minutes. Mice were treated daily with ip injections of IFNτ (5×10^5 U/day) or PBS starting three days prior to immunization. Blood was collected 24 h prior to (Figure 1A) and 24 h after (Figure 1B) aerosolized OVA exposure. Direct ELISA was performed to detect OVA-specific IgE levels. Two to three mice per group were used, and average absorbance is shown. Control absorbance using a normal mouse serum has been subtracted out from each dilution point. Statistical significance for the inhibition of OVA-specific IgE antibody production was shown by Student's *t* test at all dilutions (except for the 10,000 dilution) for IFNτ treatment as compared to PBS treatment ($p<0.05$).

Figures 2A-2C show the histological evaluation of OVA-immunized mice after treatment with PBS or IFNτ. BALB/C mice were immunized with OVA and exposed to aerosolized OVA on day 20 after immunization and treated with PBS or IFNτ as previously described. Twenty-four hours after aerosolized OVA treatment, lungs from non-immunized (Figure 2A), PBS treated (Figure 2B), and IFNτ treated (Figure 2C) mice were extracted,

fixed, embedded in paraffin, sectioned and stained with hematoxylin and eosin for inflammatory cells. Arrows indicated the epithelium of the bronchiole.

Figure 3 shows IL-4 levels in sera of OVA-immunized mice treated with PBS or IFNτ. BALB/C mice were immunized with OVA and exposed to aerosolized OVA and treated with PBS or IFNτ as previously described in Figure 1 description. Blood was collected 24 h after aerosolized OVA exposure, and a sandwich ELISA for IL-4 was performed. Two to three mice per group were used, and average amount (ng) of IL-4 is shown. Control level from naive mouse serum was subtracted from the PBS and IFNτ levels.

Figures 4A and 4B show *in* vivo treatment of OVA-immunized mice with IFNτ reduces OVA-stimulation of splenocytes. BALB/C mice were immunized with OVA and exposed to aerosolized OVA and treated with PBS or IFNτ as previously described in the Figure 1 legend. Spleen cells (5×10^5 cells/well) were cultured with OVA at 100 μg/ml for 72 h, after which the cultures were pulsed with tritiated thymidine. PBS-treated splenocytes were also incubated with BSA and MBP at 100 μg/ml (Figure 4B). Cell associated radioactivity was quantified 12 h later using a β-scintillation counter, and data from one of three experiments are presented as mean cpm of quadruplicate wells ± SD. Statistical significance for the inhibition of OVA-induced cell proliferation by IFNτ treatment as compared to PBS treatment was shown using Student's *t* test ($p<0.001$).

Figure 5 shows *in* vitro treatment of splenocytes with type I IFNs inhibit OVA-specific proliferation. BALB/C mice were immunized by ip injection of OVA mixed with aluminum hydroxide and boosted 7 days later. The mice were exposed to aerosolized OVA (1% w/v) on day 19 and 20 for 20 minutes. Spleen cells (5×10^5 cells/well) were cultured with 15000 U/ml of various IFNs and media in the presence or absence of 100 μg/ml OVA for 84 h, after which the cultures were pulsed with tritiated thymidine. Cell associated radioactivity was quantified 12 h later using a β-scintillation counter, and data from one of three experiments are presented as mean cpm of quadruplicate wells ± SD. Inhibition of OVA specific splenocyte proliferation by all the IFNs was statistically significant as

compared to OVA-specific splenocyte proliferation of OVA-sensitized medium-treated cells as shown by Student's *t* test ($p<0.001$).

Figures 6A-6C show immunoblot detection of mouse and human IgE in culture supernatants taken from ovalbumin (OVA)-sensitized mouse splenocytes or human myeloma B cells treated with various IFNs or media. Figure 6A includes Lane 1, control mouse IgE; lane 2, RPMI 1640 supplemented with 10% FBS; lanes 3 and 4, 84 h supernatants from naive mouse splenocytes cultured in the absence or presence of OVA, respectively; lanes 5 and 6, 84 h supernatants from PBS-treated OVA-sensitized mouse splenocytes cultured in the absence or presence of OVA, respectively; lanes 7 and 8, 84 h supernatant from IFNτ-treated OVA-sensitized mouse splenocytes in absence or presence of OVA, respectively. Figure 6B includes Lane 1, control mouse IgE; lane 2, RPMI 1640 medium only; lane 3, 84 h splenocyte culture in the absence of OVA; lanes 4, 5, 6, and 7, 84 h splenocyte (5×10^5 cells/well) cultures with OVA in presence of media, IFNτ, IFNτ/IFNα chimeric, and IFNαD, respectively. Figure 6C includes Lane 1, RPMI 1640 medium only; lanes 2, 3, 4, and 5, IgE producing U266BL cells, which were starved overnight, and incubated at 2×10^5 cells/well for 96 h in the presence of media, 1.0×10^4 U/ml IFNαD, IFNτ/IFNαD chimeric, and IFNτ, respectively.

Figure 7 shows the inhibition of proliferation of the IgE-producing human myeloma B cell line U266 by type I IFNs. The IgE-producing U266BL cells, which were starved overnight, were incubated at 2×10^5 cells/well in the presence of 1.0×10^4 U/ml of IFNτ, IFNτ/IFNαD chimeric, IFNαD, and media 72 h. Cultures pulsed with tritiated thymidine, and cell associated radioactivity was quantified 12 h later using a β-scintillation counter, and data from one of three experiments are presented as mean cpm of quadruplicate wells ± SD. Percent cell viability, as measured by trypan blue exclusion test, is presented above each bar. Statistical significance for the inhibition of cell proliferation was shown by Student's *t* test for all the IFN treatments as compared to the media treatment ($p<0.001$).

Figure 8 shows the metabolic activity of human peripheral blood mononuclear cells (HPBMC) after treatment with IFNs. HPBMC were cultured in the presence of varying

concentrations (250 to 100,000 U/ml) of IFNτ, IFNαD, and IFNτ/IFNαD chimeric for seven days. Metabolic activity of HPBMC was assessed by measuring cell proliferation and viability as described in the Materials and Methods and reported here as percent of the untreated control. Values for HPBMC treated with ovine IFNτ and IFNτ/IFNα chimeric were not significantly different from the untreated control whereas values for HPBMC treated with human IFNα were significantly different ($p<0.05$) from the untreated controls as determined using the Wilcoxon signed-rank test.

Detailed Description of the Invention

The subject invention concerns novel therapeutic and prophylactic methods for treating any condition where suppression or inhibition of IgE production is useful or beneficial, including allergic diseases and other IgE-related diseases or conditions. Disease conditions that can be treated according to the subject methods include, but are not limited to, allergic rhinitis, atopic dermatitis, bronchial asthma and food allergy. In the methods of the present invention, an effective amount of a composition comprising a type I IFN, such as IFNα, IFNβ, IFNτ or IFNω, or a chimeric IFN, is administered to a person having a condition where suppression or inhibition of IgE production is clinically desirable.

In one embodiment of the subject invention, an effective amount of IFNτ is administered to a person or animal afflicted with, or predisposed to, an allergic condition or other IgE-associated condition. The IFN used in the subject methods can be from any animal that produces the IFN, including but not limited to, primate, ovine, bovine and others.

In another embodiment of the subject invention, a mammalian IFN that has an amino acid sequence that provides the low toxicity of IFNτ with the bioactivity of other type I IFNs is used in the subject methods to treat a person or animal afflicted with, or predisposed to, an allergic condition or other conditions or diseases where suppression of IgE production or response is beneficial. In a preferred embodiment, an effective amount of a chimeric IFN comprising a mammalian IFNτ amino terminus and a human type I IFN carboxy terminus, such as that from IFNα, is administered to a person afflicted with, or predisposed to, an

allergic condition or other IgE-associated condition. More preferably, the chimeric IFN protein comprises amino acid residues 1-27 of ovine IFNτ and amino acid residues 28-166 of human IFNα. In an exemplified embodiment, the IFNα is IFNαD.

The subject invention also concerns methods for suppressing IgE production and cell proliferation *in vivo* and *in vitro* using a type I interferon. As exemplified herein, splenocytes taken from an ovalbumin (OVA) immunized animal using either IFNτ or a chimeric IFNτ protein suppressed OVA-induced proliferation and IgE production. Thus, the methods of the subject invention can be used to suppress IgE production in an animal or person. The methods of the subject invention can also be used to suppress IgE production *in vitro*.

The present invention also concerns methods for inhibiting B cell and T cell responses, including cell proliferation and cytokine production. As exemplified herein, type I IFNs can be used to inhibit production of IL-4. The cytokine IL-4 plays a central role in isotype switching of the B cells to IgE production.

Biologically active muteins (mutated proteins) of the subject polypeptides, as well as other molecules, such as fragments, peptides and variants, that possess substantially the same IgE-suppressive bioactivity as the subject IFN polypeptides, are contemplated within the scope of the subject methods. For example, IFNτ polypeptides that contain amino acid substitutions, insertions, or deletions that do not substantially decrease the biological activity and function of the mutant polypeptide in comparison to native polypeptide are within the scope of the present invention. Specifically contemplated within the scope of the invention are fragments of the type I IFN that retain substantially the same biological activity as the full length IFN. The muteins and fragments of IFNs can be readily produced using standard methods known in the art. For example, by using the Bal31 exonuclease (Wei *et al.*, 1983), the skilled artisan can systematically remove nucleotides from either or both ends of the polynucleotide to generate a spectrum of polynucleotide fragments that when expressed provide the IFN fragment encoded by the polynucleotide.

Therapeutic application of the subject polypeptides and compositions containing them can be accomplished by any suitable therapeutic method and technique presently or prospectively known to those skilled in the art. The polypeptides can be administered by any suitable route known in the art including, for example, oral, parenteral, subcutaneous, or intravenous routes of administration. Administration of the polypeptides of the invention can be continuous or at distinct intervals as can be readily determined by a person skilled in the art.

The subject invention also concerns chimeric IFN polypeptides and the polynucleotides that encode them. In one embodiment, the chimeric IFNs comprise ovine and human IFN regions. Preferably, a chimeric IFN protein of the invention comprises an ovine IFNτ amino terminus and a human IFNα carboxy terminus. In an exemplified embodiment, the chimeric IFN protein comprises amino acid residues 1-27 of ovine IFNτ and residues 28-166 of human IFNαD. The polynucleotide sequences encoding the chimeric IFNs of the present invention can be readily constructed by those skilled in the art having the knowledge of the amino acid sequences of the subject polypeptides. As would be appreciated by one skilled in the art, a number of different polynucleotide sequences can be constructed due to the degeneracy of the genetic code. The choice of a particular nucleotide sequence could depend, for example, upon the codon usage of a particular expression system.

Compounds useful in the subject invention can be formulated according to known methods for preparing pharmaceutically useful compositions. Formulations are described in detail in a number of sources which are well known and readily available to those skilled in the art. For example, *Remington's Pharmaceutical Science* by E.W. Martin describes formulations which can be used in connection with the subject invention. In general, the compositions of the subject invention will be formulated such that an effective amount of the bioactive polypeptide is combined with a suitable carrier in order to facilitate effective administration of the composition. The compositions used in the present methods can also be in a variety of forms. These include, for example, solid, semi-solid, and liquid dosage forms, such as tablets, pills, powders, liquid solutions or suspension, suppositories, injectable

and infusible solutions, and sprays. The preferred form depends on the intended mode of administration and therapeutic application. The compositions also preferably include conventional pharmaceutically acceptable carriers and diluents which are known to those skilled in the art.

The compounds of the subject invention can also be administered utilizing liposome technology, slow release capsules, implantable pumps, and biodegradable containers. These delivery methods can, advantageously, provide a uniform dosage over an extended period of time.

Examples of carriers or diluents for use with the subject polypeptides include ethanol, dimethyl sulfoxide, glycerol, alumina, starch, and equivalent carriers and diluents. To provide for the administration of such dosages for the desired therapeutic treatment, new pharmaceutical compositions of the invention will advantageously comprise between about 0.1% and 45%, and especially, 1 and 15% by weight of the total of one or more of the polypeptides based on the weight of the total composition including carrier or diluent.

All patents, patent applications, provisional applications, and publications referred to or cited herein are incorporated by reference in their entirety to the extent they are not inconsistent with the explicit teachings of this specification.

Materials and Methods

Interferons.

The ovine interferon tau (IFNτ) gene was expressed in *Pichia pastoris* using a synthetic gene construct (Heeke *et al.*, 1996). IFNτ was secreted into the medium and was purified by successive DEAE-cellulose and hydroxylapatite chromatography to electrophoretic homogeneity as determined by SDS-PAGE and silver staining analysis. The purified protein had a specific activity of 2.9 - 4.4 x 10^7 U/mg protein as measured by antiviral activity using a standard viral microplaque reduction assay on MDBK (Pontzer *et al.*, 1991). The recombinant human IFNαD was from Biosource International, Camarillo, CA. The "humanized" IFNτ/IFNαD chimeric protein was constructed using residues 1-27

of the ovine IFNτ and residues 28-166 of the human IFNαD and was expressed in *Pichia pastoris* as previously described for ovine IFNτ (Heeke *et al.*, 1996).

IFNτ was administered intraperitoneally (ip) at 5 x 10^5 U/mouse daily starting 96 h prior to immunization and continuing everyday thereafter for a month. Control mice received PBS.

Immunization of mice.

BALB/C mice were immunized ip with 10μg of ovalbumin (OVA) (Sigma, St. Louis, MO) precipitated with 5 mg aluminum hydroxide gel in a total volume of 100μL. Aluminum hydroxide gel was prepared as previously described (Revoltella *et al.*, 1969; Warner *et al.*, 1968). Mice were immunized again 7 days after the initial immunization using the same protocol. The mice were exposed to aerosolized OVA from 1% OVA (w/v) in PBS on days 19 and 20 after immunization. Aerosolization was performed for 20 min using the Pari ls Jet + nebulizer and compressor (Pari Respiratory Equipment, Inc., Midlothian, Virginia). Mice were housed and cared for at the Animal Resource Center (University of Florida), and all experimental animal uses were approved by the Institutional Animal Care and Use Committee (IACUC).

Histological evaluation.

The lungs of OVA-immunized mice that had been exposed to aerosolized OVA were intratracheally perfused with 4% paraformaldehyde solution. The lungs were fixed for 2-3 days in the same solution after which lung samples were embedded in paraffin and sectioned. Samples were then stained with hematoxylin and eosin. Also, blood smears were prepared on slides from the same mice, and slides were stained with the "LEUKOSTAT" staining kit (Fisher Scientific, Pittsburgh, PA) for the determination of differential white blood cell count. A total of 150 white blood cells were evaluated.

Proliferation assay.

Spleen cells taken from mice 21 days after immunization from PBS or IFNτ-treated mice were cultured at 5 x 10^5 cell/well in presence of OVA for 72 to 84 h in RPMI 1640 medium containing 10% FBS. In other assays, PBS-treated mouse splenocytes were incubated at 5 x 10^5 cells/well in presence of OVA and various IFNs (10,000 to 15,000 U/ml) for 72 to 84 h. The cultures were pulsed with [^{3}H]-thymidine (1.0 uCi/well; Amersham, Indianapolis, IN) and harvested 12 h later on to filter paper discs using a cell harvester. Cell associated radioactivity was quantified using a β-scintillation counter and activity reported in CPM. Proliferation assays on the U266BL myeloma B cells were also carried out by incubating the cells in RPMI 1640 medium overnight prior to culturing 4 x 10^5 cells/well with various IFNs at 10,000 to 15,000 U/ml in RPMI 1640 containing 4% FBS. Cultures were incubated for 72-84 h after which cells were pulsed with [^{3}H]-thymidine prior to harvest 12 h later. Cell associated radioactivity was quantified using β-scintillation counter and activity reported in CPM. The U266BL cell line, an IgE producing myeloma that was isolated from the peripheral blood of a patient, provides a system to assess the direct effects of IFNτ on an IgE producing cell (Nilsson *et al.*, 1970). This cell line allows one to study the effects of IFNτ on B cells with ongoing IgE synthesis.

Enzyme Linked Immunoadsorbent Assay.

OVA was resuspended in binding buffer (0.1 M carbonate/bicarbonate, pH 9.6) and absorbed onto the flat bottoms of plastic 96-well tissue culture wells overnight at 4°C at a concentration of 2μg/well and subsequently evaporated to dryness. The plates were treated with blocking buffer, 5% powdered milk in PBS, for 2 h in order to block nonspecific binding and then washed three times with PBS containing 0.05% Tween 20. Various dilutions of sera from BALB/C mice which were IFNτ-treated or PBS-treated or nonimmunized (naive) mice were added to the wells and incubated for 3 h at room temperature. After extensive washing, rabbit anti-mouse IgE antibody (Accurate, NY) was added. Plates were washed three times prior to addition of 1:1000 diluation of horse radish

peroxide (HRP) conjugated goat anti-rabbit immunoglobulin (Amersham Pharmacia Biotech, Piscataway NJ). Color development was monitored at 490 ηm in an ELISA plate reader (BioRad, Richmond, CA) after the substrate solution (0.002M o-phenylenediamine dihydrochloride, 0.012% H_2O_2, 0.05 M Na Citrate, 0.05 M citrate) was added and the reaction terminated with 2M H_2SO_4.

For the detection of IL-4 in blood, sera samples were collected from PBS- or IFNτ treated mice and incubated in 96 well plates that had rabbit polyclonal anti-mouse IL-4 antibody (Biosource Int., Camarillo, CA) bound to it. After washing, 25μg/ml of rat monoclonal anti-mouse IL-4 biotinylated antibody was added for 1 h incubation. A 1:1000 dilution of HRP-conjugated avidin was added after the incubation and washings, and substrate color development was monitored as described above. The limit of detection of the IL-4 ELISA was 7 ng/ml.

Western blot.

Culture supernatants from both IFN or media treated OVA-sensitized splenocytes, and U266BL myeloma B-cells, were loaded at 10ug/lane (total protein) on 15% and 10% SDS-PAGE READY GELS (BioRad, Richmond, CA) respectively, and run at 100 volts. Overnight transfer onto nitrocellulose membrane was carried out, after which the membrane was blocked with 5% milk in Tris-buffered saline pH 7.5, 0.1% Tween 20 for 1 h. Immunoblots were incubated with a 1:1000 dilution of either goat anti-human IgE (Biosource Int., Camarillo, CA) coupled to HRP or rabbit anti-mouse IgE (Accurate, NY). The mouse IgE blot was incubated further after three washes with HRP conjugated anti-rabbit Ig (Amersham Pharmacia Biotech, Piscataway, NY) for 1 h. Blots were washed and analyzed through film development.

Toxicity Assays of IFNs.

Toxicity assays using human peripheral blood mononuclear cells (HPBMC) were carried out by culturing HPBMC in the presence of varying concentrations of IFNτ, IFNαD,

and chimeric IFNτ/IFNαD for seven days. Metabolic activity of HPBMC was assessed using WST-1 (Boehringer-Mannheim, Indianapolis, IN), which measures cell proliferation and viability based on the enzymatic activity of mitochondrial dehydrogenases in viable cells.

Following are examples which illustrate procedures for practicing the invention. These examples should not be construed as limiting. All percentages are by weight and all solvent mixture proportions are by volume unless otherwise noted.

Example 1 - IFNτ inhibits production of OVA-specific IgE antibody in mice

As shown in Figure 1A, daily injections (ip) of IFNτ at 5 x 10^5 units beginning prior to OVA-aluminum hydroxide injection (ip) blocked IgE antibody production by over 50%. Further, the blocking continued even when the mice where challenged with aerosolized OVA (Figure 1B). Thus, IFNτ inhibited OVA-specific IgE antibody production under conditions where the mice were immunized to OVA by injection and challenged by inhalation.

Example 2 - Reduced inflammatory cell infiltration of IFNτ-treated mice

OVA immunized mice were challenged with aerosolized OVA following treatment with IFNτ in order to determine if the IFN treatment inhibited inflammatory cell infiltration into the lungs. IFNτ inhibition of cellular infiltration is shown in Figure 2 where lung sections of naive (Figure 2A), PBS treated (Figure 2B), and IFNτ treated (Figure 2C) mice are compared. The destruction of the integrity of the epithelial tissue lining the bronchiole of the PBS treated mice (Figure 2B) versus the protection in IFNτ treated mice (Figure 2C) was evident. Eosinophil, basophil, and lymphocytic infiltration was assessed around bronchioles and blood vessels of IFNτ and PBS treated (control) mice. Significantly fewer bronchioles had peribronchiolar aggregates of granulocytes with IFNτ treatment (20%) as compared to PBS treatment (64%) (Table I).

Table I. IFNτ reduces OVA-induced inflammatory cell infiltration into the bronchioles*

Treatment	Lung sections: Granulocyte aggregates (% Airways)	Lung sections: Lymphocyte aggregates (% Airways)
PBS	64 ± 6.0	78 ± 7.0
IFNτ	20 ± 7.0	34 ± 3.0
Naive	0	0

	Blood smears: Eosinophil (%)	Basophil (%)	Neutrophil (%)	Monocyte (%)	Lymphocyte (%)
PBS	11 ± 5.0	6.0 ± 1.0	20 ± 0.7	10 ± 1.4	58 ± 6.0
IFNτ	2.5 ± 0.7	1.5 ± 0.7	15 ± 1.4	5.0 ± 1.4	72 ± 8.0
Naive	0.2 ± 0.3	0.5 ± 0.7	19 ± 1.4	10 ± 0.7	71 ± 4.0

*Mice were treated (ip) with 5 x 10^5 U of IFNτ daily starting three days prior to OVA immunization as described in the Materials and Methods section. Airways having peribronchiolar aggregates were enumerated and divided by the total number of bronchioles examined in each section. Differential white cell counts from blood smears are presented as percent cell type. Statistical significance for the inhibition of granulocytes and lymphocyte aggregates around the bronchioles was shown by χ^2 test for IFNτ treatment as compared to PBS treatment ($p<0.001$). Statistical significance for the inhibition of eosinophil ($p<0.05$) and basophil ($p<0.1$) by IFNτ treatment as compared to PBS treatment was shown by Student's *t* test.

Also, 78% of lung bronchioles in PBS-treated mice had lymphocytic infiltration compared to 34% for IFNτ treatment. In addition, differential counts on the blood of mice showed that IFNτ-treated mice had lower levels of eosinophils and basophils as compared to those of PBS-treated groups, while neutrophil, monocyte, and lymphocyte levels were not significantly different from either the PBS-treated or naive (nonimmunized) mice. Thus, the data show that IFNτ treatment inhibits inflammatory cell infiltration into the lungs of OVA-sensitized- mice when exposed to aerosolized OVA allergen.

Example 3 - IFNτ-treated mice have lower IL-4 levels than control mice

IL-4 levels in sera of mice treated with PBS, IFNτ, or nonimmunized (naive) mice were measured after aerosolized OVA exposure, which was given 20 days after immunization. It has been shown previously that IL-4 may be necessary for inducing the IgE isotype class switch in B cells (Lanzavecchia *et al.*, 1984; Coffmann, Carty *et al.*, 1986; Coffmann, Ohara *et al.*, 1986; Rothman *et al.*, 1988). As shown in Figure 3, IL-4 levels in the IFNτ-treated group were less than half of those of the PBS-treated group.

Example 4 - *In vivo* IFNτ-treatment inhibits OVA-specific splenocyte proliferation

Spleens from nonimmunized (naive) mice and PBS- or IFNτ-treated OVA-immunized mice were removed 20 days after OVA immunization in order to determine the inhibitory effect of IFNτ treatment on OVA induced proliferation. Splenocytes were incubated in the presence of OVA for 84 h after which proliferation was assessed. As shown in Figure 4, significantly reduced proliferation in response to OVA was observed in splenocytes from IFNτ-treated mice as compared to PBS-treated control mice. This proliferative activity was specific for OVA since bovine serum albumin (BSA) and myelin basic protein (MBP) did not activate splenocytes (Figure 4 inset). Thus, *in vivo* IFNτ treatment of allergen-primed mice inhibited cellular proliferation in response to allergen.

Example 5 - *In vitro* IFN treatment of OVA-sensitized splenocytes inhibits OVA-specific splenocytes proliferation

OVA sensitized splenocytes were treated *in vitro* with various IFNs in order to determine their effect on previously sensitized cells. Spleens were removed 20 days after OVA immunization and after aerosolized OVA treatment, and cultured with various type I IFNs for 84 h after which proliferation was assessed. In addition to ovine IFNτ treatment, human IFNαD, and chimeric IFNτ/IFNαD were also tested for their effects on OVA induced proliferation. The chimeric was tested as a potential for "humanized" IFNτ for possible human therapy. As shown in Figure 5, both IFNτ and IFNαD inhibited OVA-specific

splenocyte proliferation. Furthermore, the IFNτ/IFNαD chimeric, which contained amino acid residues 1-27 of ovine IFNτ and residues 28-166 of human IFNαD, also had an inhibitory effect. Thus, treatment of OVA-sensitized splenocytes *in vitro* with type I IFNs suppressed cell proliferation.

Example 6 - Type I IFNs inhibit mouse and human IgE production

Immunoblots for the detection of IgE antibodies were performed on culture supernatants taken from the proliferation assay experiments performed in Figure 4 and 5. As shown in Figure 6A, IgE was detected in cultures containing PBS-treated splenocytes that were incubated in the presence of OVA. There was little or no IgE in supernatants from splenocytes of IFNτ-treated mice. Immunoblots for detection of IgE in culture supernatants from *in vitro* IFN treatment of OVA sensitized mouse splenocytes showed an inhibition of IgE production by all of the type I IFNs as compared to the media control (Figure 6B). The chimeric IFNτ/IFNαD protein and the IFNαD protein were better inhibitors than was IFNτ, however.

The U266BL human myeloma cell line, which produces IgE antibodies constitutively was also incubated with the type I IFNs in order to determine if the IFNs had a direct effect on the human IgE-producing B cells. Cells were starved overnight prior to treatment with various type I IFNs, including the IFNτ/IFNαD chimeric. After incubation with the IFNs for 96 h, supernatants were collected and IgE levels were detected by immunoblot. As shown in Figure 6C, IgE levels were lower in the IFN treated groups as compared to the media control. Thus, type I IFNs inhibit U266BL human myeloma cells and OVA-specific mouse B cells from producing IgE antibodies.

Example 7 - IFN inhibition of proliferation of the human IgE-producing myeloma cells

The U266BL myeloma cells were cultured in the presence of 10,000 U/ml of IFNs for 72 h, after which proliferation was measured. All IFNs inhibited proliferation of the cells by about 50% or more with IFNαD being the most effective and IFNτ being the least

effective (Figure 7). Viabilities were determined and showed that the IFNαD was the most toxic (67% viability) as compared to the IFNτ (80% viability) and the IFNτ/IFNα chimeric (75% viability). The IFNτ/IFNαD chimeric suppressed proliferation more effectively than IFNτ but not as effectively as IFNαD. Thus, type I IFNs, with various toxicity levels, inhibit the cell proliferation of the human IgE producing cell line, U266BL.

Example 8 - Lack of toxicity of the IFNτ/IFNαD chimeric on human peripheral blood mononuclear cells (HPBMC)

The IFNτ/IFNαD chimeric was compared with recombinant ovine IFNτ and recombinant human IFNαD for toxicity on HPBMC. After seven days of treatment of the HPBMC with various concentrations of IFNs (250 to 100,000 U/ml), toxicities were measured based on the enzymatic activity of the mitochondrial dehydrogenases in viable cells. As shown in Figure 8, human IFNαD was toxic at concentrations of 1,000 to 100,000 U/ml as compared to ovine IFNτ and IFNτ/IFNαD chimeric, which did not show toxicity at any concentration. Thus, the IFNτ/IFNαD chimeric, like ovine IFNτ, lacked the toxicity associated with human IFNαD.

It should be understood that the examples and embodiments described herein are for illustrative purposes only and that various modifications or changes in light thereof will be suggested to persons skilled in the art and are to be included within the spirit and purview of this application and the scope of the appended claims.

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Claims

We claim:

1. A method for suppressing or inhibiting IgE production, said method comprising administering an effective amount of a type I interferon, or a biologically active mutein, fragment, variant or peptide thereof.

2. The method according to claim 1, wherein said type I interferon is selected from the group consisting of IFNα, IFNβ, IFNτ and IFNω.

3. The method according to claim 2, wherein said type I interferon is IFNτ.

4. The method according to claim 1, wherein said type I interferon is a chimeric IFN comprising part of at least two IFNs selected from the group consisting of IFNα, IFNβ, IFNτ and IFNω.

5. The method according to claim 4, wherein said chimeric IFN comprises a mammalian IFNτ amino terminus and a human type I IFN carboxy terminus other than IFNτ.

6. The method according to claim 5, wherein said mammalian IFNτ amino terminus is from a mammal selected from the group consisting of primate, ovine and bovine.

7. The method according to claim 5, wherein said chimeric IFN comprises amino acid residues from about 1 to about 27 of ovine IFNτ and amino acid residues from about 28 to about 166 of human IFNα.

8. The method according to claim 7, wherein said IFNα is IFNαD.

9. The method according to claim 1, wherein said type I interferon is administered to a person or animal in need of suppression or inhibition of IgE production.

10. The method according to claim 1, wherein said suppression or inhibition of IgE production occurs through inhibition of B-cell IgE secretion or inhibition of B-cell proliferation.

11. The method according to claim 9, wherein said type I interferon is administered by routes selected from the group consisting of oral administration, parenteral administration, subcutaneous administration and intravenous administration.

12. The method according to claim 11, wherein said person or animal is afflicted with, or predisposed to, an IgE-related condition.

13. The method according to claim 12, wherein said IgE-related condition is an allergic condition selected from the group consisting of allergic rhinitis, atopic dermatitis, bronchial asthma and food allergy.

14. The method according to claim 1, wherein said type I interferon is administered *in vitro*.

15. The method according to claim 1, wherein said type I interferon is formulated in a pharmaceutically acceptable carrier or diluent.

16. A composition comprising a chimeric type I interferon, or a biologically active mutein, fragment, variant or peptide thereof, which is capable of suppressing or inhibiting

IgE production, wherein said chimeric IFN comprises part of at least two IFNs selected from the group consisting of IFNα, IFNβ, IFNτ and IFNω.

17. The composition according to claim 16, wherein said suppression or inhibition of IgE production occurs through inhibition of B-cell IgE secretion or inhibition of B-cell proliferation.

18. The composition according to claim 16, wherein said chimeric IFN comprises a mammalian IFNτ amino terminus and a human type I IFN carboxy terminus other than IFNτ.

19. The composition according to claim 18, wherein said mammalian IFNτ amino terminus is from a mammal selected from the group consisting of primate, ovine and bovine.

20. The composition according to claim 18, wherein said chimeric IFN comprises amino acid residues from about 1 to about 27 of ovine IFNτ and amino acid residues from about 28 to about 166 of human IFNα.

21. The composition according to claim 20, wherein said IFNα is IFNαD.

22. The composition according to claim 16, wherein said chimeric IFN is recombinantly produced and is expressed in *Pichia pastoris*.

23. A polynucleotide that encodes the chimeric IFN of claim 16.

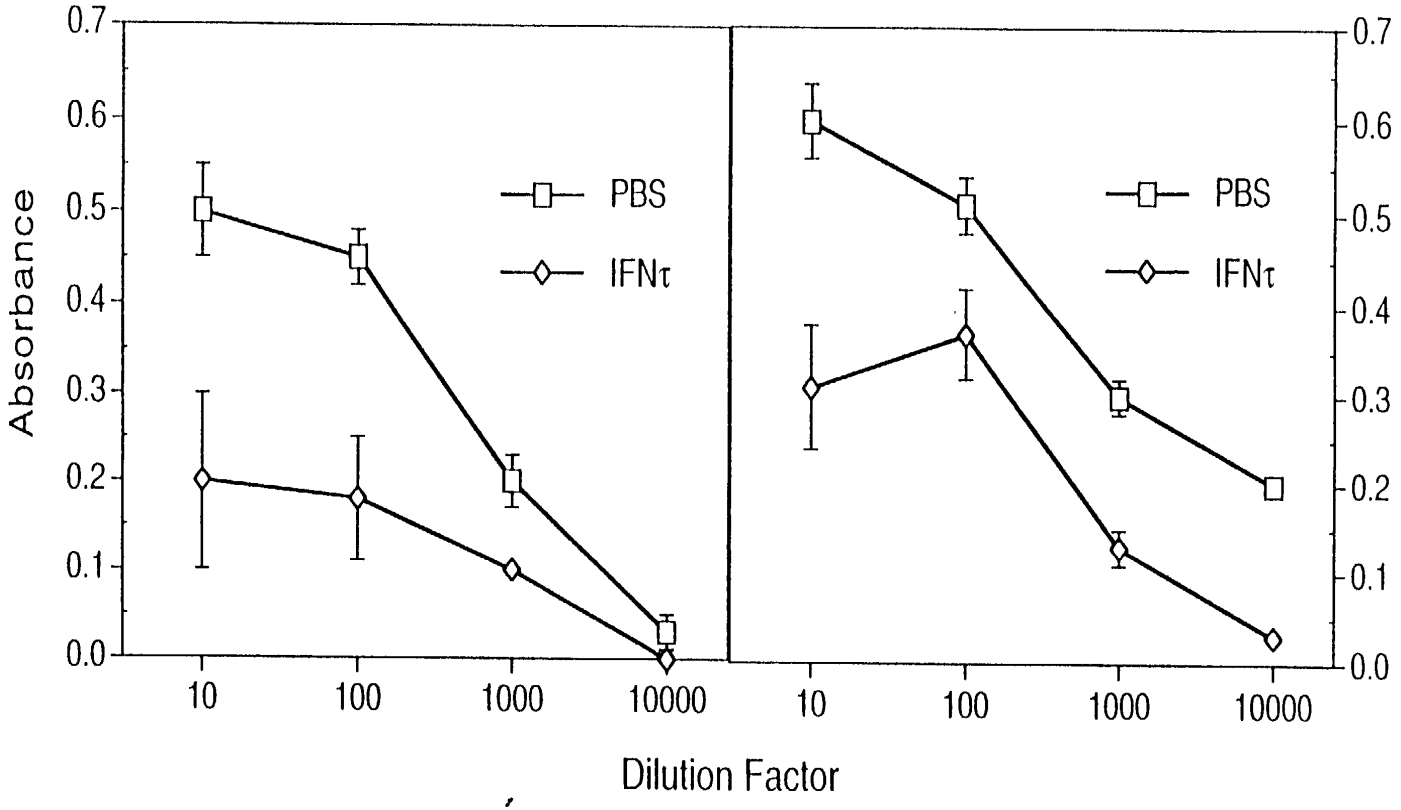
24. A method for suppressing or inhibiting IL-4 production, said method comprising contacting an immune cell with a type I interferon, or a biologically active mutein, fragment, variant or peptide thereof.

Abstract

The subject invention concerns novel methods and materials for treating patients afflicted with allergic conditions, such as allergic rhinitis, atopic dermatitis, bronchial asthma and food allergy. The method of the subject invention comprises administering interferon tau (IFNτ) or a chimeric IFN (ovine IFNτ (1-27)/human IFNαD (28-166)) to a person afflicted with an allergic condition. When administered, IFNτ and chimeric IFN suppress the production of IgE antibodies without toxic side effects. The subject invention also concerns chimeric ovine/human IFNs which can be used in the methods of the invention.

FIG. 1A

FIG. 1B



SCAN 12

FIG. 2A

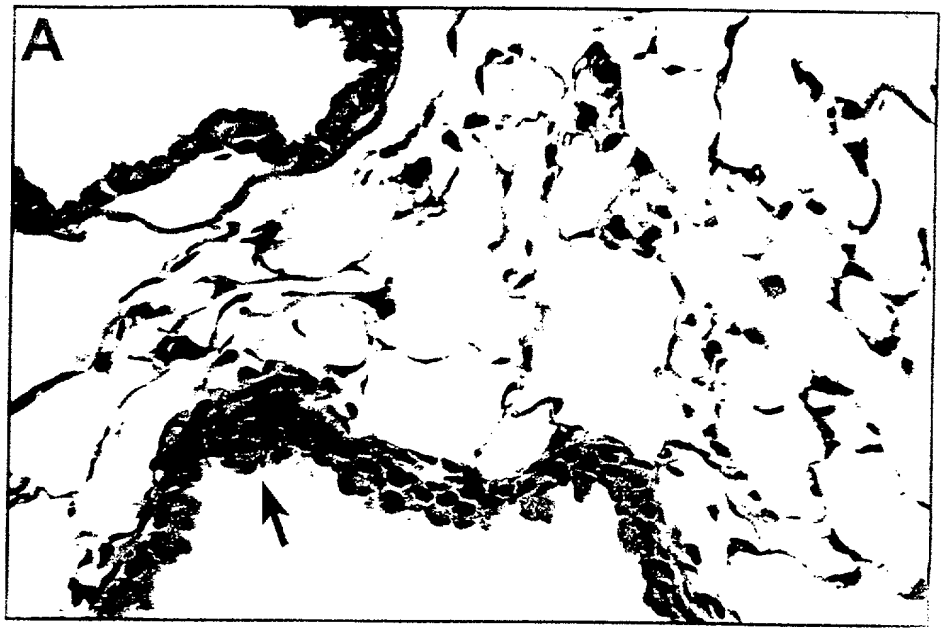


FIG. 2B

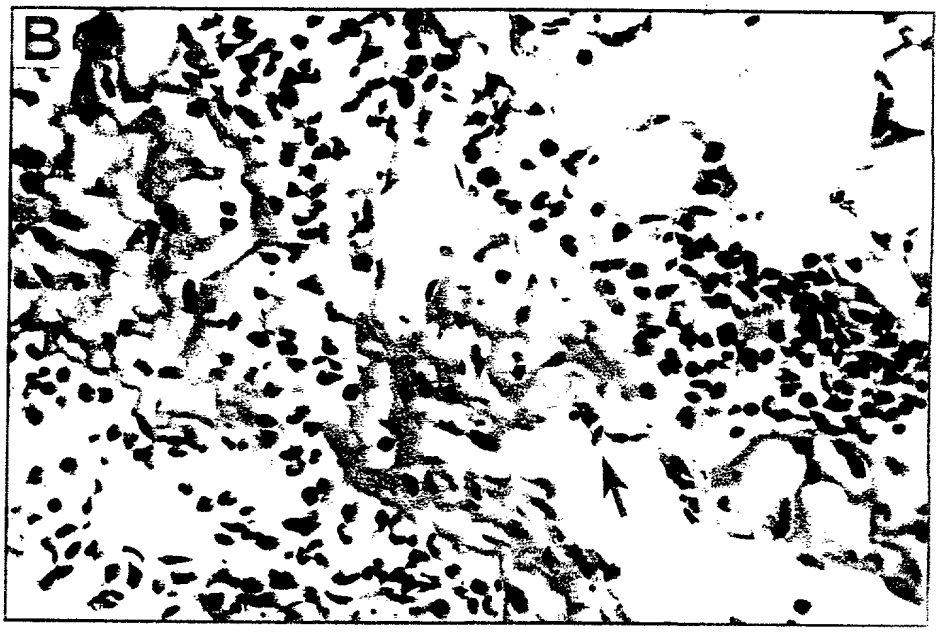
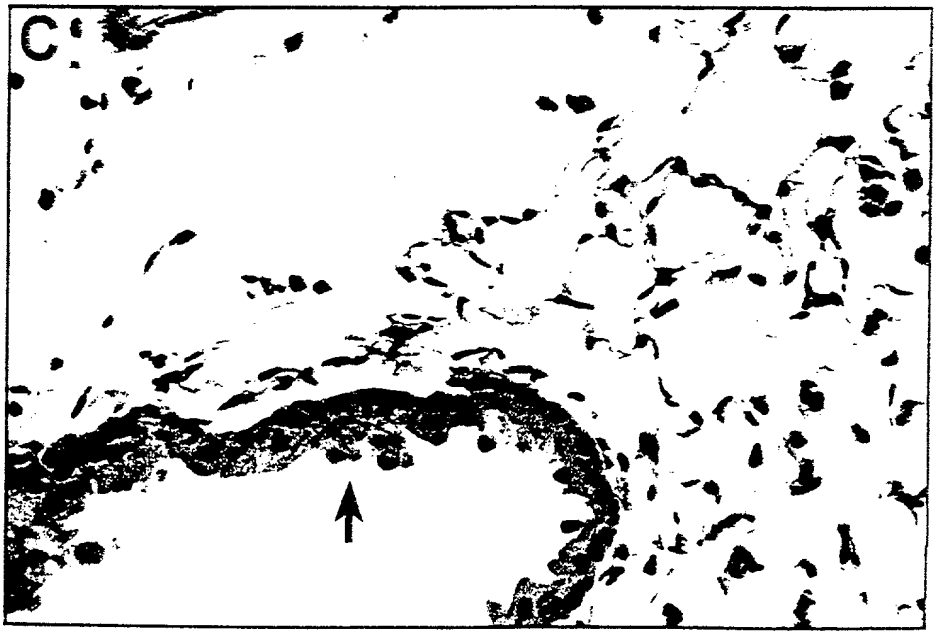


FIG. 2C



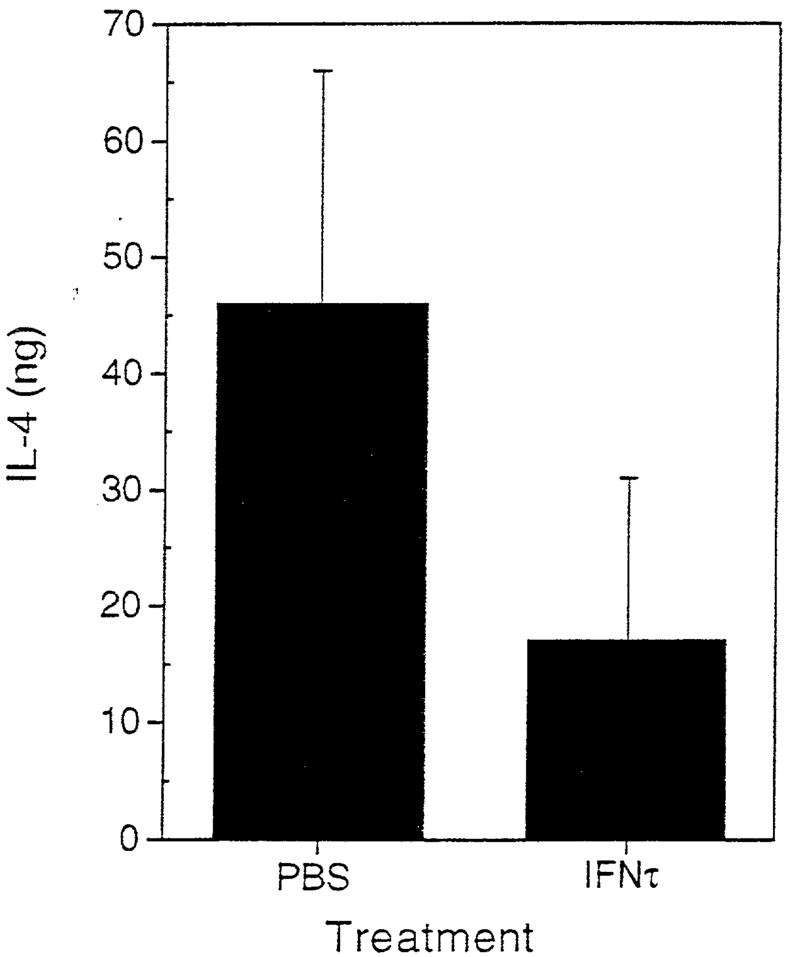


FIG. 3

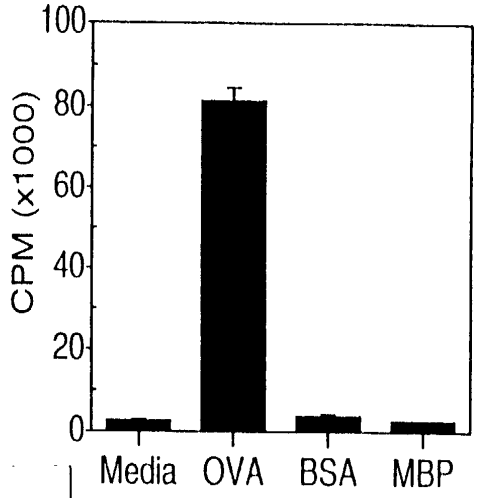

100
80
60
40
20
0
CPM (x1000)
Media
OVA
BSA
MBP

FIG. 4B

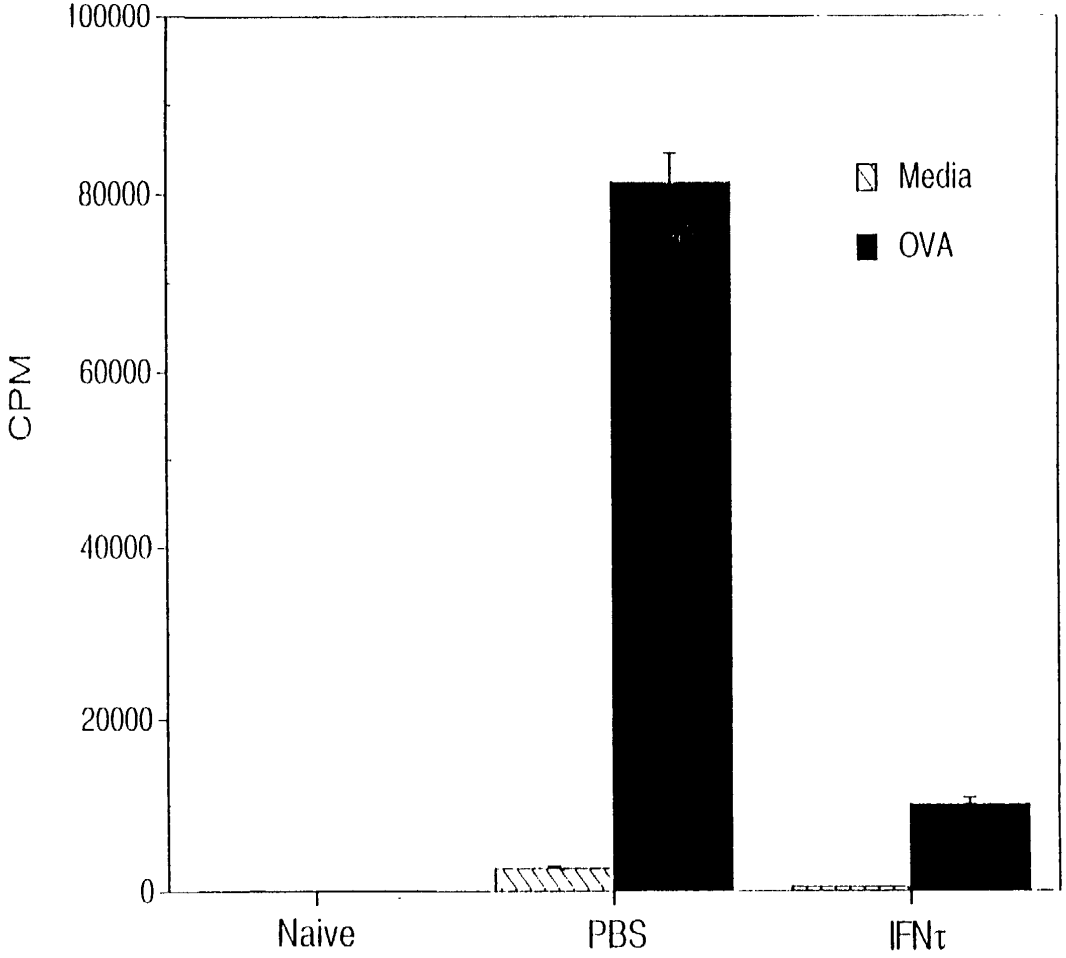

100000
80000
60000
40000
20000
0
CPM
Media
OVA
Naive
PBS
IFNτ

FIG. 4A

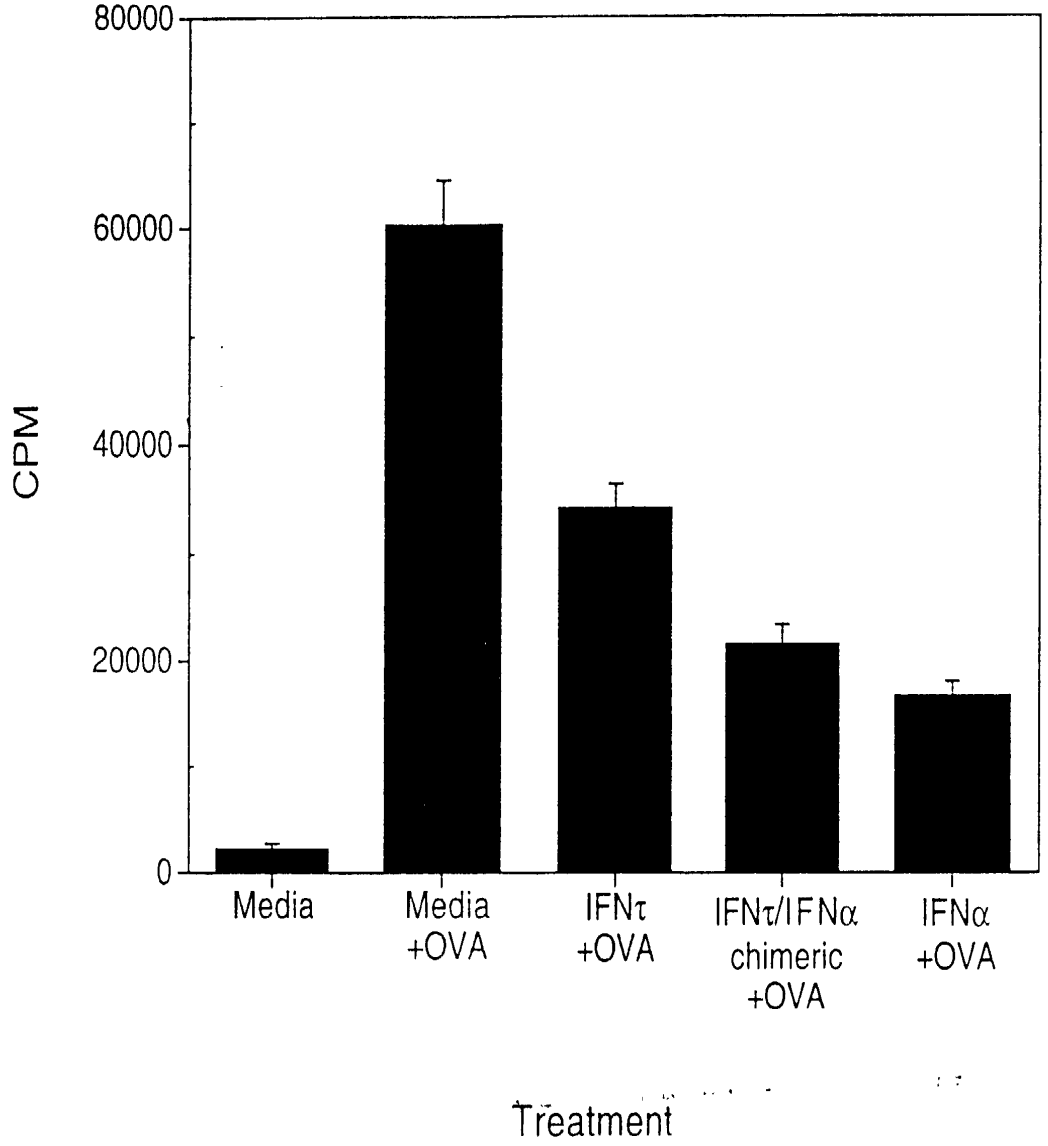

80000
60000
40000
20000
0
CPM
Media
Media +OVA
IFNτ +OVA
IFNτ/IFNα chimeric +OVA
IFNα +OVA
Treatment

FIG. 5

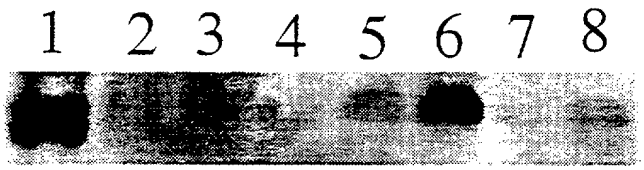


FIG. 6A

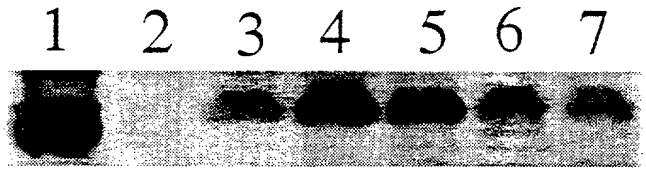


FIG. 6B

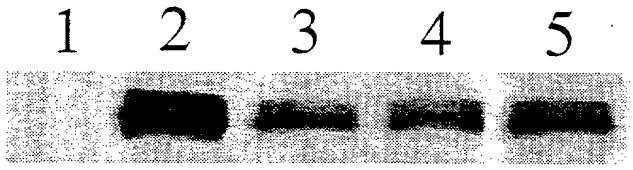


FIG. 6C

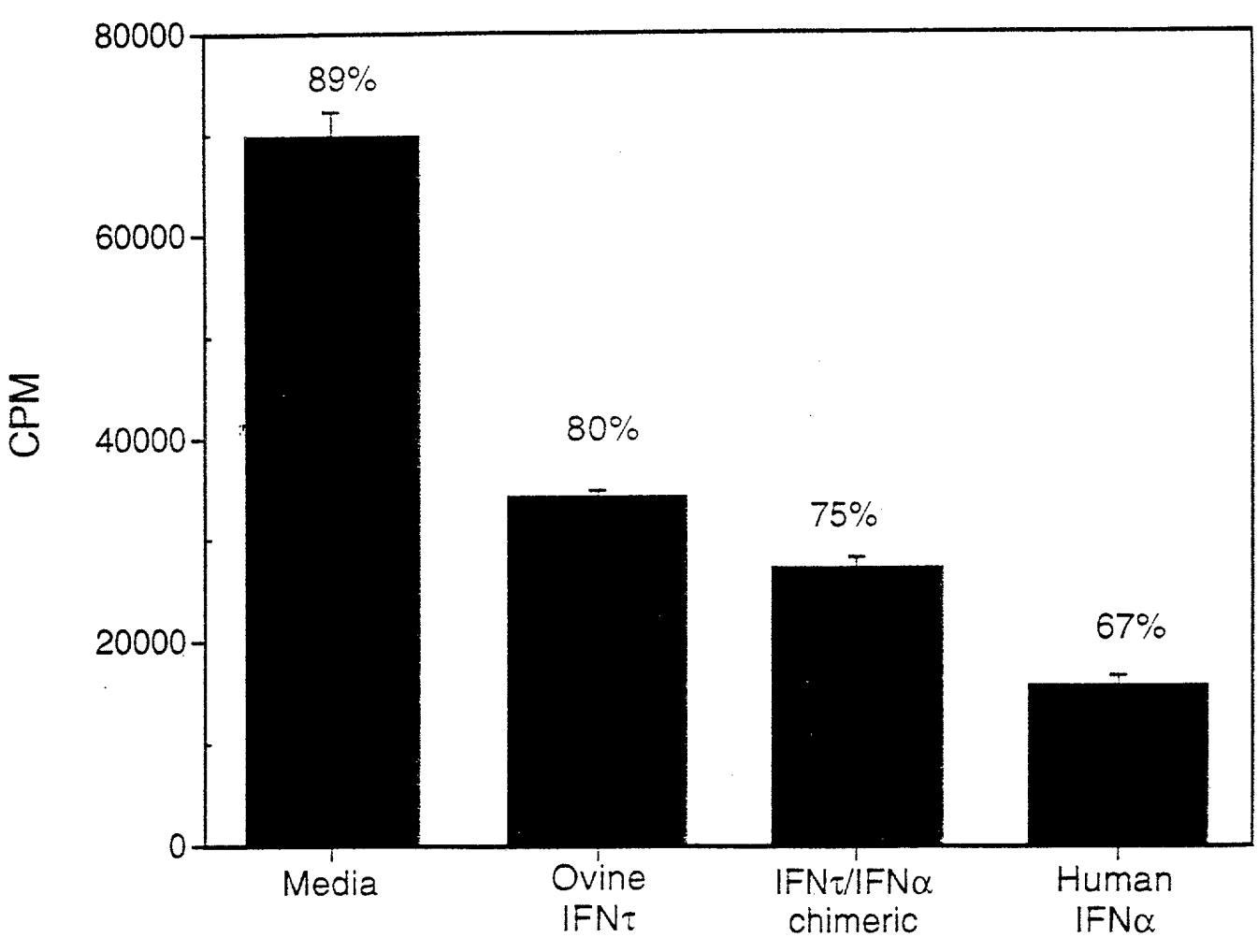


FIG. 7

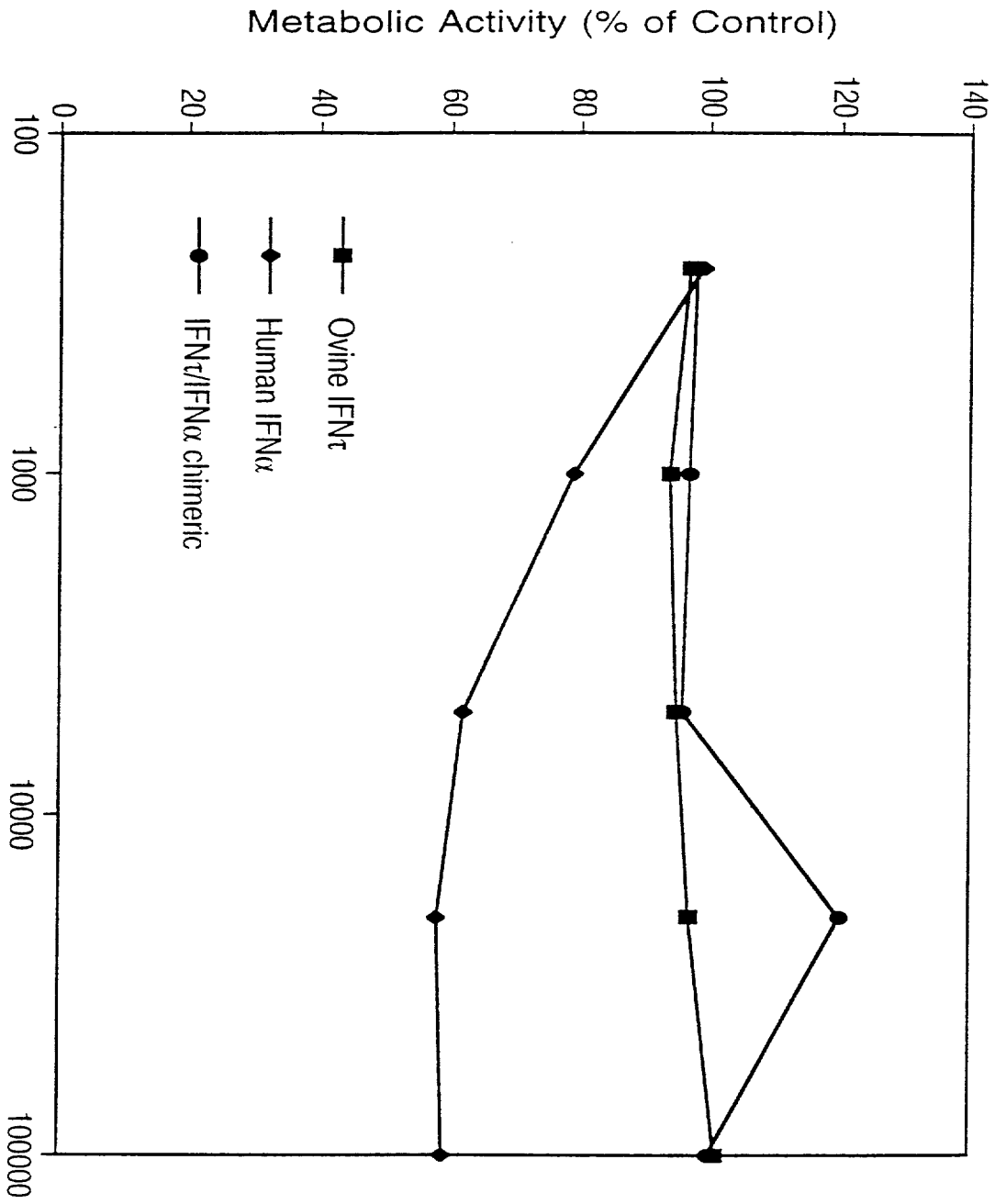

Metabolic Activity (% of Control)
140
120
100
80
60
40
20
0
100
1000
10000
100000
IFN (U/ml)
Ovine IFNτ
Human IFNα
IFNτ/IFNα chimeric

FIG. 8

Docket No. UF-243X

DECLARATION (37 CFR 1.63) AND POWER OF ATTORNEY

As a below-named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name; and

I believe that I am the original, first, and sole inventor (if only one name is listed below), or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **MATERIALS AND METHODS FOR INHIBITION OF IgE PRODUCTION** the specification for which

☒ is attached hereto.

☐ was filed _____, Serial No. _____.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code §119 and/or §365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Application Serial No.	Country	Filing Date	Priority Claimed

I hereby claim priority benefits under Title 35, United States Code §119 of any provisional application(s) for patent listed below:

Application Serial No.	Filing Date	Priority Claimed
60/151,026	August 27, 1999	Yes

I hereby claim the benefit under Title 35, United States Code, §120 and/or §365 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application(s) in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which became available between the filing date of the prior application and the national or PCT international filing date of this application:

Application Serial No.	Filing Date	Status (patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I hereby appoint the following persons registered to practice before the Patent and Trademark Office as my attorneys with full power of substitution and revocation to prosecute this application and all divisions and continuations thereof and to transact all business in the Patent and Trademark Office connected therewith: David R. Saliwanchik, Reg. No. 31,794; Jeff Lloyd, Reg. No. 35,589; Doran R. Pace, Reg. No. 38,261; Christine Q. McLeod, Reg. No. 36,213; Jay M. Sanders, Reg. No. 39,355; James S. Parker, Reg. No. 40,119; Jean Kyle, Reg. No. 36,987; Frank C. Eisenschenk, Reg. No. 45,332; Seth M. Blum, Reg. No. 45,489; Glenn P. Ladwig, Reg. No. P-46,853.

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Residence _____ Citizenship _____

Post Office Address _____

_____

_____ Date _____

Signature of Fourth Joint Inventor